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Critical Care Medicine

Clinical Center

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By Joseph E. Parrillo, M.D.*

Over the past 70 years, the progressive incorporation of increasingly more sophisticated technology into the diagnosis and treatment of many medical diseases has brought major changes in the practice of medicine. High technology is nowhere more visible than in the rapidly progressing field of intensive care, or critical care medicine.

Yet this relatively new field depends mostly on people, not machines; for the people who run critical care units—and their energy, skills, and love for humanity—make the critical care environment the most advanced means available to reverse rapidly progressing disease and restore a patient's health.

Critical care medicine is a multidisciplinary and multispecialty medical and nursing field concerned with patients who have sustained, or are at risk of sustaining, acute, life-threatening single or multiorgan system failure due either to disease or injury. Critical care medicine involves doctors, nurses, technicians, and other support personnel, as well as the technology that is needed for the intensive care unit to function optimally.

The Critical Care Patient

Patients who require critical care have certain characteristics. They have usually sustained an acute medical problem that is very serious, commonly life-threatening, that can be reversed by medical intervention.

Reversability is very important to the concept of critical care. The ultimate goal of critical care is not only to get patients through the life-threatening event, but to help them recover sufficiently to return home to a normal life.

There are, unfortunately, many acute, life-threatening conditions that cannot be remedied by any known medical intervention and are therefore not appropriately treated with critical care. Much of the debate in the field of critical care today centers around the question of which diseases are indeed reversible, how much of the process can be reversed, and to what degree critical care therapy should be employed in situations where life is seriously threatened.

The critical care environment is very complex, but overall it provides two broad capabilities. First, critical care patients receive minute-to-minute observation and diagnosis of changes in body physiology. In addition, the critical care environment provides rapid therapy to reverse physiological dysfunction such as changes in heart rhythm, blood potassium level, or a seriously low blood pressure. This coupling of diagnosis and therapy on a minute-to-minute, sometimes even second-to-second, basis is what differentiates critical care from other forms of medical care.

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Historical Overview

Therapeutic intervention is a relatively late arrival to medical care. The rationale for today's intensive care units (ICU) was born over 100 years ago when Florence Nightingale noted that she could provide better care by designating a separate area for the sickest patients. Such patients generally needed the most care, which then consisted of morphine for pain relief and, occasionally, surgery to stop bleeding. The concept of a designated observation area for the sickest patients provides the rationale for today's intensive care units. It was seen in the earliest hospitals, where the sickest patients were commonly placed next to the nursing station. However, the therapeutic options were very limited.

World War II and the Korean War added several new innovations. Postoperative recovery rooms were established to monitor patients after general anesthesia and major surgery. It was found that respiratory problems could often be averted by placing the post-op patients in one area where nurses and doctors watched them constantly. Therapeutic maneuvers, by this time, were improving, and now included reintubation of the trachea for respiratory failure, tracheostomy (creating a hole in the upper trachea to alleviate upper airway obstruction), surgery, and rapid blood administration for severe bleeding, and vasopressor therapy to increase low blood pressure.

The next step in the evolution of modern critical care was the development of the coronary care unit. In the 1950's, it was realized that drugs or electrical shock applied to the chest could be used to convert certain life-threatening heart rhythms back to normal. This important discovery led to the creation of multibed units for monitoring cardiac rhythm in the early 1960's so that potentially lethal rhythms could be prevented or treated.

Over the past 20 years, the concepts learned in postoperative recovery rooms have been combined with the technologies of the coronary care unit to produce the modern intensive care unit. Critical care can be given in subspecialty units such as neurologic, pulmonary, cardiac, kidney, or in multispecialty or general intensive care units that care for any critically ill patient. Two rationales support the general intensive care unit. It is more economical, especially for smaller hospitals, to combine all resources into one area. And the types of personnel and technology necessary for the various subspecialty units are quite similar.
Therefore, the broad field of critical care medicine was developed in the early 1970's to provide care for all critically ill patients regardless of organ system involvement.

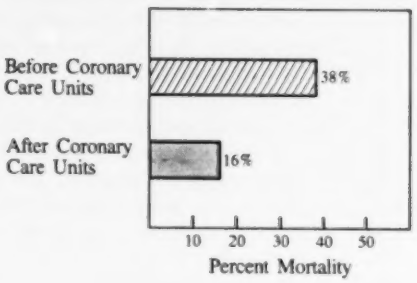
Do ICU's Work?

The central issue facing critical care medicine regards the efficacy of the intensive care unit: how successful is the ICU in decreasing mortality and morbidity? The answer to this question is complex and depends largely on the probability of survival outside of an ICU and on the ability of the ICU to reverse the underlying disease pathophysiology. ICU's are clearly efficacious in many disease processes and clearly of no benefit in others. In between the two extremes lies a gray area where intensive care may or may not be useful and the outcome is often difficult to predict.

Critical care is most beneficial when the underlying condition is able to be reversed. For example, respiratory failure due to drug overdose has a mortality rate of 100 percent without good ICU care, but 1 to 2 days of ventilation therapy in the ICU is clearly lifesaving. Respiratory failure caused by reversible neurological or muscular dysfunction results in a 95 percent mortality rate without respiratory support, but only 5 percent with appropriate care in an ICU.

Mortality for Diseases Treated in Intensive Care Units

Acute Myocardial Infarction



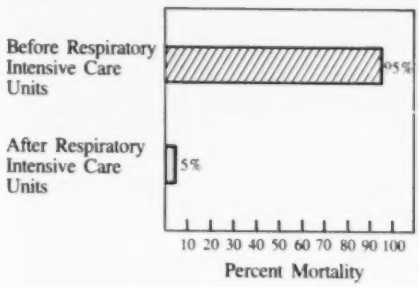
Acute heart rhythm changes occur very commonly in the first few minutes or days after a myocardial infarction (heart attack). Most studies suggest an in-hospital mortality of about 38 percent outside the coronary care unit. However, mortality is only about 16 percent in a coronary care unit with appropriate monitoring and intervention. Thus, critical care therapy reduces the mortality rate for this particular disease by more than half.

Respiratory failure due to reversible neurological or muscular dysfunction produces about 95 percent mortality without respiratory support. But mortality is only 5 percent with appropriate respiratory care in an ICU.

In other diseases, the results are not as clear-cut but still favorable. For example, septic shock, characterized by a low blood pressure induced by a severe bloodstream infection, has a death rate greater than 90 percent if the patient is not supported with intensive care technology and personnel. In the modern ICU, this mortality has dropped to about 60 percent.

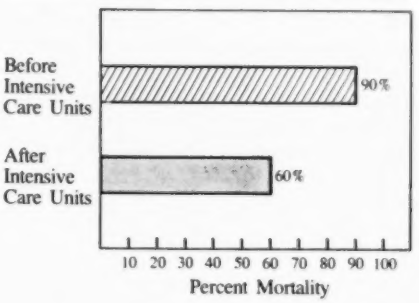
Mortality for Diseases Treated in Intensive Care Units

Respiratory Failure Secondary to Reversible Neurologic or Muscular Dysfunction


Before Respiratory Intensive Care Units
95%
After Respiratory Intensive Care Units
5%
10 20 30 40 50 60 70 80 90 100
Percent Mortality

Mortality for Diseases Treated in Intensive Care Units

Shock Secondary to Sepsis



ICU Technology

An important aspect of ICU care is not only getting patients through the life-threatening event, but bringing them to total recovery. This is the ultimate goal of ICU care as well as general medical care. In an ICU, technology and machines play a vital role in restoring health. Technology is used for monitoring the patient's condition, to aid in diagnosis, and in intervention tactics or therapy.

While in the ICU, the patient is usually continously attached to a number of monitoring systems. The most important of these is the continuous electrocardiogram. Electrodes attached on the skin over the chest transmit an electrocardiogram tracing to a monitor that shows heart rate and rhythm. Printouts of the electrocardiogram can be made and most intensive care units have a central monitoring station where a nurse can follow the rhythms of many patients so that serious changes may be recognized at once.

Blood pressure can be monitored continuously in the critical care environment, using a catheter placed in the brachial artery. An accurate blood pressure reading is shown on a digital monitor.

Continuous monitoring of the heart rate and blood pressure is vital for following the patient's course, determining the trend, and seeing the effect of therapy as it is given. It allows therapy to be instituted or changed on a second-to-second basis. Certain heart rhythms can be lethal almost immediately and the blood pressure can go from normal to nothing in a matter of seconds when a patient is in shock. Therefore, accurate monitoring of blood pressure and heart rate on a beat-to-beat basis is essential.

The pressure inside the heart can also be monitored, both on the arterial side and on the venous side, with catheters that are pushed along the arteries and into the heart's chambers. The pressure inside the pulmonary artery can be determined by placing a catheter directly into the pulmonary artery through the venous side of the heart.

These pressures can indicate how the heart is filling and contracting and enable doctors to decide whether to institute fluid therapy or administer medication to increase the force of contraction of the heart.

Catheters are sometimes inserted with the help of x-ray machines or portable fluoroscopy. In another method that does not require the use of x-rays, a skilled doctor can place a catheter by watching the tracing that the catheter is transmitting to the monitor as it is being pushed through the vessels and into the heart.

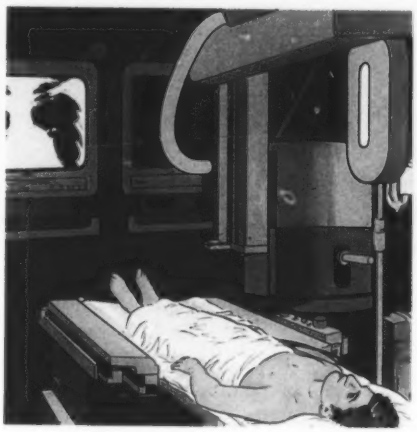
The pulmonary artery catheter is used in a technique known as thermodilution, which involves injecting salt water into the vessel to determine cardiac output. It is also possible to calculate the amount of resistance that the heart is meeting when it pumps, and drug therapy can be instituted to reduce that resistance and make it easier for the heart to pump.

Depending on the patient's illness, doctors can choose to monitor different types of pressures. The aortic pressure can be monitored in the radial or brachial artery to follow changes in arterial pressure. The pulmonary-capillary wedge pressure can be determined by passing a catheter through the right side of the heart and along the pulmonary artery into the lung vessel. This reading enables doctors to differentiate whether poor cardiac output is being caused by heart failure or by a lack of fluid in the body.

There are a number of ways to access the circulation. The internal jugular vein is commonly used to place a catheter into the right side of the heart, or a catheter can be put into the radial or femoral artery. The skin over the area where the catheter is inserted is numbed to make the placement of the catheter essentially painless, and catheters can stay in place for days or weeks with relative safety and are removed after the patient has recovered from acute illness.

Many vital functions and metabolic values can change drastically in minutes in a patient who is critically ill. Therefore, the ability to process laboratory data rapidly is an important function of the critical care environment. Much of the technology involved in critical care medicine is designed to hasten laboratory results and reduce the need to move the patient. For example, the blood gas analyzer allows the medical staff to determine the pH factor and the amount of oxygen and carbon dioxide in the blood in as little as 30 seconds. Evaluating blood gases quickly can be critical for patients with severe airway problems.

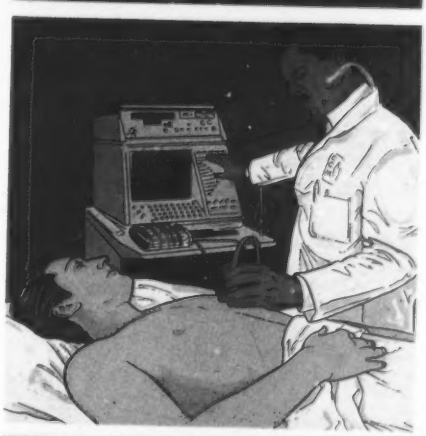
Portable fluoroscopy is used for guiding intravascular catheter placement while allowing the patient to remain in the same bed, and more sophisticated x-ray machines are available in some ICU's to perform more complex studies of heart function and hemodynamics.

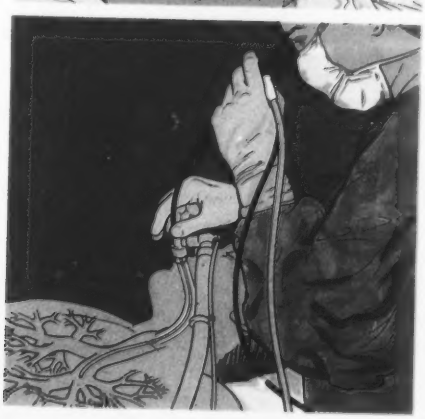


Nuclear scanning involves injecting a tracer dose of nuclear material into the bloodstream and using x-rays to study the function of the heart and determine whether certain organs are receiving sufficient bloodflow. Multiorgan system failure from inadequate blood flow is one of the most common causes of death in ICU's.

Echocardiography uses sonar to evaluate the size and function of the heart and its valves, and it can show whether there is fluid in the pericardial sac around the heart. Remarkably accurate, echocardiography causes no side effects or discomfort.

Bedside bronchoscopy, useful for both diagnosis and treatment of patients with pneumonia, uses a fiber optic tube passed into the trachea through the patient's endotracheal tube. This is advantageous for diagnosing and relieving pneumonia. The bronchoscope allows the doctor to see into the bronchi and can be used to remove a small piece of tissue for diagnosing the infectious agent causing the disease. It is also used for clearing the thick mucous secretions that often develop with severe pneumonia.





Intervention

A major therapeutic intervention of the ICU is the ventilator, a device which forces oxygen and air into the lungs through a tube inserted directly into the trachea. The ventilator is essential to maintain respiration in patients with severe muscular or neurological damage or patients who are too weak to breathe adequately on their own. The ventilator can be used safely in such circumstances for days or even weeks.

In some conditions such as pneumonia or acute respiratory distress syndrome the patient is unable to utilize a sufficient amount of oxygen from breathing air in the room to sustain life. The ventilator can be used to deliver increased amounts of oxygen until the lung condition has healed enough to allow the patient to breathe adequately.

A relatively new therapy called positive end expiratory pressure (PEEP) involves applying pressure to the lungs on a relatively continuous basis, particularly at end expiration to keep the airways open. High amounts of oxygen can actually damage the lungs, but PEEP keeps the airways open, even if they are damaged, with nontoxic levels of oxygen.

Medications and fluids used in the ICU require very precise control, because very small changes in amounts given can have profound effects on the cardiovascular and pulmonary function of a patient. Thus, machines are used to control the drip rates of medicines being administered and offer a range of from 1 drop to 5,000 drops per hour.

Direct current electrical defibrillation, developed in the 1950's, uses electricity to convert serious arrhythmias. Although medications are generally used to correct heart rhythms, there are times when electrical currents are the safest and best method.

The intra-aortic balloon pump, also called counterpulsation, provides a means for increasing cardiac output and improving cardiac function. It involves a small balloon placed in the aorta that inflates between beats and deflates with every beat. It is used to assist the heart temporarily, particularly after acute myocardial infarction or recent cardiac surgery.

Despite the considerable technology of the intensive care unit, an ICU cannot have all of the hospital's diagnostic and therapeutic procedures contained within its walls. Therefore, sophisticated mobile equipment makes it possible to transport very sick patients to other parts of the hospital while skilled personnel continue to monitor and support the patient.

An example of the characteristic medical care provided by an ICU is illustrated by a 24-year-old car accident victim who sustained blunt steering wheel trauma to his chest. He was admitted to the ICU barely conscious and with a very low blood pressure. His condition was diagnosed as pericardial tamponade in which blood accumulates in the pericardial sac around the heart, causing pressure and prohibiting blood to fill the heart's chambers. The diagnosis was made by pressure tracing with the use of an arterial and pulmonary artery catheter.

An echocardiogram confirmed fluid in the pericardium. Doctors removed about 50 cc's of blood from the pericardial sac. The pericardium pressure, filling pressure of the heart, and blood pressure returned to normal. The patient recovered and left the hospital in about a week.

The People of the ICU

Although machines receive much of the attention in ICU's, it is the people who truly determine the level of medical care. Critical care medicine requires long hours of hard work. Good administration is especially important in an ICU and special skills are required of the head nurse, medical director, and technical supervisor to inspire the staff to perform the work necessary and face the inevitable frustrations of critical care medicine. Serious errors can result if the technology is misused, and the ICU must be carefully run by persons experienced in the pitfalls of critical care medicine so that problems can be avoided.

The critical care nurse must have many unique attributes. Extensive basic and clinical training is required, and the ICU nurse must be dedicated to hard work and have an almost compulsive desire for accuracy. A good critical care nurse is firm yet kind, sensitive to minor patient needs, and can react quickly when necessary to prevent catastrophe. Maturity, sensitivity, and a sense of humor that can break tense moments are important characteristics. The ICU nurse knows where to press to stop the hemorrhage when the blood hits the wall, and is ready to listen when the family needs a shoulder to cry on. He/she is truly a special person.

The critical care physician must have leadership to direct the critical care team through many intricate procedures as well as knowledge of all aspects of medicine and a large number of technical procedures. Sensitivity and love of humanity help the physician to effect appropriate care without depriving patients of dignity and enable him/her to aid the patient's family and loved ones, particularly when death cannot be avoided.

The machinery and high technology of an ICU are useless, even dangerous, if not cared for and operated by experts; therefore, the technical staff is a vital part of the health care team. Good ICU technicians show compassion and concern for the patients in the ICU and must be highly skilled in preventing and repairing the many things that can go wrong with equipment.

Dedication and teamwork are the most important aspects of critical care medicine. The overall care of a critically ill patient is exceedingly complex requiring thousands of individual pieces of data to be collected and hundreds of decisions to be made daily. Communication, cooperation, and mutual respect are essential.

Continuity of care is another major aspect of critical care medicine. After successful treatment in the ICU, patients always require substantial amounts of further care to restore functional capacity. Often there is an extended convalescence and the patient may require additional medical and nursing care, physical therapy, and help dealing with the limitations imposed by the illness.

Critical care is more than a medical discipline. Reassurance and emotional support are among the most important therapeutic interventions, especially for hopelessly ill patients. Providing support to family and friends, who are often devastated by the sudden critical illness of a loved one, is also part of the job; all members of the ICU team must be able to help those involved to deal with the stress a serious illness causes.

Medications and technology have limits and the ICU staff must often face the reality of death. There is much that can be done for a dying patient; easing a patient's death by offering spiritual support as well as physical comfort is a vital part of critical care medicine. The medical and nursing staff must show extreme sensitivity to determine and meet the wishes and needs of each patient.

Continuing education is essential for all critical care staff members because the field changes so rapidly. Medical knowledge advances at a truly awesome pace. In a 3-4 year period, more than 50 percent of our knowledge in technology and medicine will have changed. The next 10 years will bring more advances in critical care technology and in understanding of disease processes than has been made in the past 10 years. Education, communication, and constant dedication are needed to be ready for each new advance that may save or prolong life. These advances will include better technology as well as better understanding of the disease process and ways to reverse altered physiology.

At NIH we are doing our best to produce those advances in medical science that are of such importance. But we will not lose sight of the fact that the nurses, physicians, and technicians of the ICU ultimately determine the quality of medical care a patient receives.